

Phytotoxicology 1998 Investigation: Algoma Steel Inc. - Sault Ste. Marie

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Background:

Algoma Steel Incorporated is an integrated primary iron and steel producer located on the St. Mary's River in Sault Ste. Marie, Ontario. Integrated mills process iron ore in blast furnaces where coke is burned to heat the ore. As it burns, coke releases carbon monoxide which chemically reduces the ore, consisting primarily of iron oxides, to metallic iron. Limestone added to the furnace provides an additional source of carbon monoxide as well as acting as a flux to fuse with silicates in the ore. The resulting calcium silicate floats to the top of the molten iron and is drawn off as slag.

A critical material in steel making is the coke. Coke consists mainly of carbon (90+%) and is produced by distilling coal. Coke provides the high heating value to smelt the iron ore and is also the source of carbon in steel. Integrated mills produce their own coke in coke ovens. The ovens are arranged in 'batteries' consisting of narrow vertical chambers. The heat to distill the coal is generated by burning gases in spaces between adjoining chambers. The volatile compounds released by the distillation are condensed to produce coal tar while the non-condensed gases are recovered and burned to distill fresh charges of coal.

Polycyclic Aromatic Hydrocarbons:

During coke production there are inevitable emissions of volatilized coal tar or of coal gas to the atmosphere. Major constituents of coke oven emissions are a class of organic compounds known as polycyclic aromatic hydrocarbons (PAHs). PAHs consist of three or more fused aromatic rings. Some consist only of carbon and hydrogen atoms while others have other atoms substituting carbon in the ring or function groups substituting hydrogen atoms. Consequently, it is possible to have a great diversity of PAHs. It is noteworthy that PAHs are not necessarily constituents of coal but can be formed during the coal distillation process.

The boiling points of PAHs are usually high enough so that they will not persist in the atmosphere in vapour form, but will condense onto particulates which act as nuclei. Naphthalene is frequently reported to exist in the atmosphere in vapour form, despite its 218°C boiling point. However, naphthalene sublimates and since this compound consists of only two rings it is not, strictly speaking, a **polycyclic** aromatic hydrocarbon.

Because of the tendency of PAHs to condense onto particulates, their fate in the atmosphere in terms of dispersion and deposition characteristics, is dependant on the behaviour of the particulate nuclei. Consequently, small particles will be transported greater distances than larger particles and can theoretically contain a higher mass to volume ratio of adsorbed PAHs. However, since the greater the dispersion distance, the greater the dilution, ambient air concentrations of PAHs, either in vapour or particulate form, are invariably higher near a point source.

The primary concern about PAHs is that some are considered probable human carcinogens. One of these, benzo(a)pyrene, has been the subject of considerable toxicological research and is the only PAH compound for which Ontario has an ambient air interim standard. This concentration, which is 1.1 nanograms per cubic metre per 24 hours is regularly exceeded at a MOE monitoring station located near a residential neighbourhood near the Algoma Steel complex.

Investigation Procedures:

The investigation which is the subject of this report was conducted on August 18 and 19, 1998 and consisted of collections of surface soil samples at 20 locations and tree foliage samples at 20 locations. These sampling locations were located at distances varying from about 300 to 3,800 metres from the coke ovens at the Algoma Steel complex, and covered an arc from WNW to SE of the ovens.

The soil sampling locations were typically sodded lawns of residential properties or parks and school playgrounds which appeared to be undisturbed and therefore exposed to deposition of air-borne contaminants for extended periods of time. Locations near heavily travelled roads were purposely excluded to avoid influence from vehicle exhaust, particularly from diesel vehicles, since PAHs are emitted from such mobile sources.

The tree foliage sites consisted of locations where there was a Norway maple tree, again away from major roads, and removed from sheltering influences of buildings or other trees. Norway maple was selected because it was the most common tree species in the investigation area and provided a receptor with consistent surface characteristics.

Because of the necessity to locate suitable sites for both media, the concomitant soil and foliage sampling locations were usually not at the same property and could be as far as 400 metres apart. Figure 1 represents these locations on a map that was derived from an Ontario Base Map produced from aerial photography flown in 1978. Because this base map is 20 years old, some newly constructed streets may not be indicated.

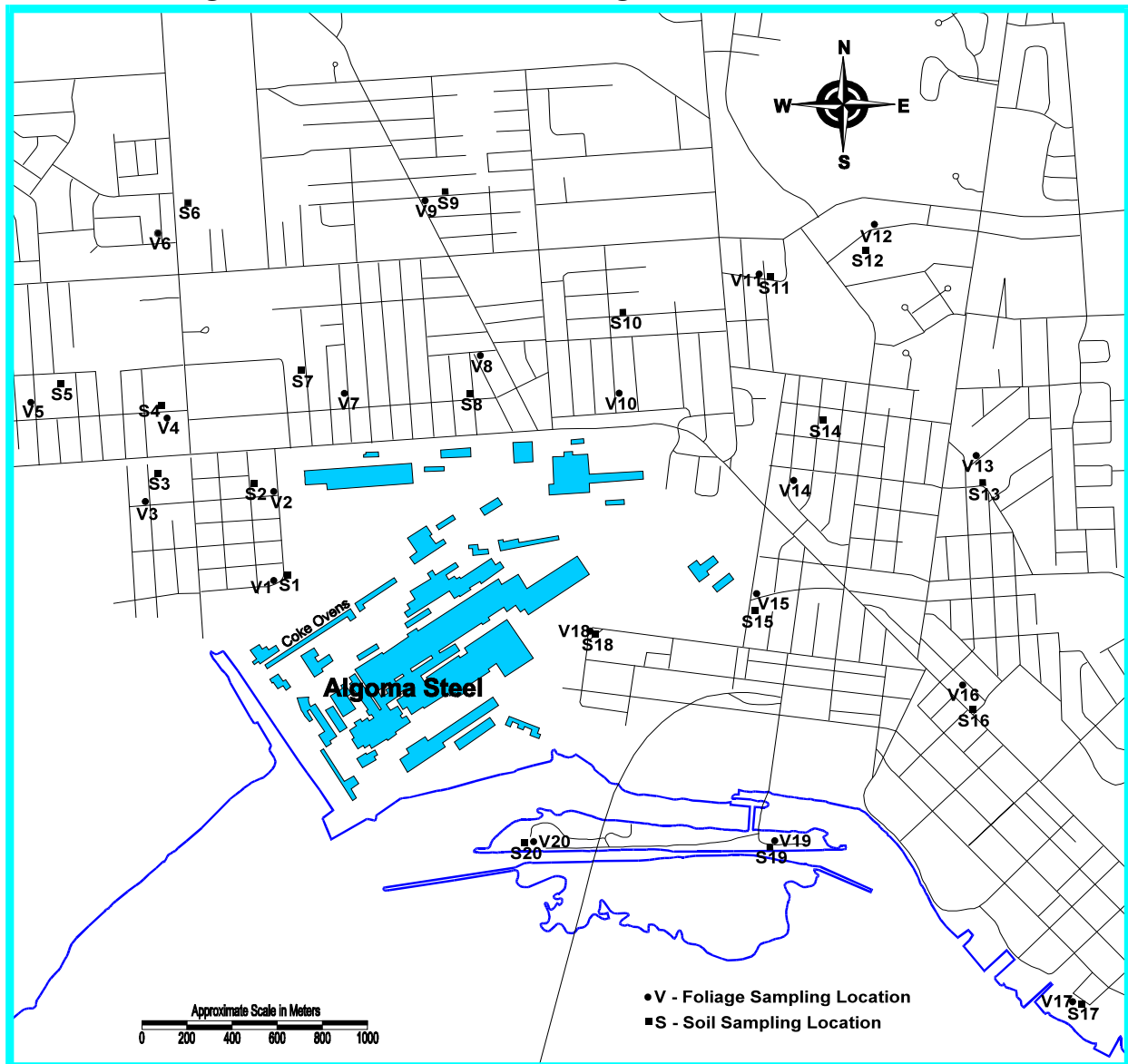
After a suitable soil sampling location was identified, the location was documented with a sketch map showing the actual sampling location with respect to permanent features such as roads and buildings. All sampling equipment that would be in contact with the sample was washed with a high-phosphate detergent, rinsed with deionized water, and then successively rinsed with acetone and hexane. The sample containers consisted of amber glass jars with aluminum foil lids. These containers were previously washed with a detergent solution followed by several deionized water rinses and were provided by the analytical laboratory.

A sampling location consisted of an area about 10 metres by 10 metres within the residential lawn or park/school property. About 12 cores of soil to a depth of five centimetres were randomly removed with a soil coring device consisting of a hollow, two centimetre diameter, stainless steel tube fitted with a cutting tip. The individual cores were placed into a stainless steel bowl, dis-aggregated, homogenized and transferred to a labelled sample jar.

The Norway maple foliage sampling consisted of documenting the tree location and using a tree branch pruner on extension poles to cut a branch from the side of the canopy that faced the Algoma Steel complex. About 50 leaves were removed by hand while wearing latex gloves and placed into a labelled sampling jar.

All samples were forwarded to the MOE Laboratory Services Branch for determination of PAH concentrations by gas chromatography - mass spectrometry (GC-MS).

**Figure 1: Tree Foliage and Surface Soil Sampling Locations
Algoma Steel, Sault Ste. Marie - August 18 & 19, 1998**



Results:

The results of the analysis of the foliage samples are reported in Table 1. Note that the concentrations are reported in nanograms per gram, also known as parts per billion, on a **fresh** weight basis. Table 2 contains the PAH concentrations in surface soil samples. These data are reported in nanograms per gram on a **dry** weight basis.

Table 1: Algoma Steel Inc. - PAHs (ng/g fw) in Norway Maple Foliage - August 18, 1998

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Naphthalene	100	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	60 <T	40 <T	20 <W	20 <W	20 <W	80 <T	20 <W	20 <W	20 <W	20 <W
Anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluoranthene	100	60 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Pyrene	60 <T	40 <T	20 <W	20 <W	20 <W	40 <T	20 <W	20 <W	20 <W	20 <W
Benzo(a)anthracene	40 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Chrysene	100	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(b)fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(k)fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Indeno(1,2,3-c,d)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Dibenzo(a,h)anthracene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19	Site 20
Naphthalene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Pyrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Chrysene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(b)fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(k)fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Indeno(1,2,3-c,d)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Dibenzo(a,h)anthracene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W

Table 2: Algoma Steel Inc. - PAHs (ng/g dw) in Surface (0-5 cm) Soil - August 19, 1998

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	OTR ₉₈	Table B ^{R/P}	Table B ^{I/C}
Naphthalene	280	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	75 <T	40,000	40,000
Acenaphthylene	140	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	47 <T	100,000	100,000
Acenaphthene	20 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	32 <T	1,000,000	1,000,000
Fluorene	60 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	39 <T	350,000	350,000
Phenanthrene	1100	100	120	420	60 <T	80 <T	60 <T	80 <T	40 <T	180	310	40,000	40,000
Anthracene	180	20 <W	20 <W	60 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	58 <T	28,000	28,000
Fluoranthene	2600	160	200	1000	140	180	120	200	120	300	560	40,000	40,000
Pyrene	2400	140	160	740	120	140	100	160	100	220	490	250,000	250,000
Benzo(a)anthracene	1300	80 <T	100	380	60 <T	80 <T	40 <T	80 <T	60 <T	100	360	40,000	40,000
Chrysene	1400	100	160	500	60 <T	80 <T	60 <T	120	60 <T	100	350	12,000	19,000
Benzo(b)fluoranthene	1400	120	120	560	80 <T	100	60 <T	120	60 <T	100	300	12,000	19,000
Benzo(k)fluoranthene	1000	80 <T	80 <T	360	60 <T	60 <T	40 <T	80 <T	60 <T	80 <T	260	12,000	19,000
Benzo(a)pyrene	1100	80 <T	120 <T	360	80 <T	80 <T	80 <T	80 <T	80 <T	80 <T	300	1,200	1,900
Indeno(1,2,3-c,d)pyrene	800	80 <T	80 <T	320	40 <W	80 <T	40 <W	80 <T	40 <W	80 <T	230 <T	40,000	40,000
Dibenzo(a,h)anthracene	320	80 <T	80 <T	160 <T	40 <W	80 <T	40 <W	80 <T	80 <T	80 <T	77 <T	1,200	1,900
Benzo(g,h,i)perylene	800	80 <T	80 <T	320	80 <T	80 <T	40 <W	80 <T	40 <W	80 <T	280 <T	40,000	40,000

	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19	Site 20	OTR ₉₈	Table B ^{R/P}	Table B ^{I/C}
Naphthalene	20 <W	20 <W	40 <T	40 <T	20 <W	20 <W	20 <W	40 <T	20 <W	60 <T	75 <T	40,000	40,000
Acenaphthylene	20 <W	20 <W	40 <T	40 <T	60 <T	20 <W	20 <W	20 <W	20 <W	80 <T	47 <T	100,000	100,000
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	180	32 <T	1,000,000	1,000,000
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	240	39 <T	350,000	350,000
Phenanthrene	80 <T	260	220	240	120	60 <T	120	200	80 <T	4,100	310	40,000	40,000
Anthracene	20 <W	40 <T	40 <T	40 <T	40 <T	20 <W	20 <W	40 <T	20 <W	420	58 <T	28,000	28,000
Fluoranthene	380	700	860	760	480	100	260	520	160	7,200	560	40,000	40,000
Pyrene	340	560	680	640	420	80 <T	220	440	120	5,100	490	250,000	250,000
Benzo(a)anthracene	180	260	320	240	220	40 <T	100	200	40 <T	2,300	360	40,000	40,000
Chrysene	180	260	340	320	240	40 <T	100	240	60 <T	2,500	350	12,000	19,000
Benzo(b)fluoranthene	180	320	480	440	440	60 <T	120	300	60 <T	3,000	300	12,000	19,000
Benzo(k)fluoranthene	160	220	320	280	280	40 <T	100	200	40 <T	1,900	260	12,000	19,000
Benzo(a)pyrene	160 <T	280	360	320	320	40 <W	120 <T	200	40 <W	2,200	300	1,200	1,900
Indeno(1,2,3-c,d)pyrene	120 <T	200	280	240	280	40 <W	80 <T	200	40 <W	1,600	230 <T	40,000	40,000
Dibenzo(a,h)anthracene	80 <T	120 <T	120 <T	120 <T	40 <W	40 <W	80 <T	80 <T	40 <W	640	77 <T	1,200	1,900
Benzo(g,h,i)perylene	120 <T	200	320	240	280	40 <W	80 <T	200	40 <W	1,500	280 <T	40,000	40,000

Discussion:

The data in Table 1 reveal that, as a rule, PAHs were not detected in Norway maple foliage during this investigation. Of the 20 samples analyzed, concentrations of all PAH compounds in 17 of the samples were reported to be below measurable levels of either 20 or 40 ng/g. These data are flagged with the remark '<W'. In two samples, some PAH compounds were reported at trace levels and flagged with '<T'. In the remaining sample, which was collected at Site 1, some compounds were abundant enough to be quantified, others were detected at trace concentrations, while the remainder were still below measurable levels.

PAHs are not naturally present in vegetation at concentrations that can be detected by routine analyses. They are also not assimilated from the soil to any appreciable extent. Therefore, it is possible to say that, in the absence of a source, PAHs in tree foliage are below the concentrations represented by the analytical detection limits. If PAHs are detected, the presence of a source must be assumed.

Site 1 is located in the residential area immediately northwest of the coke oven batteries of Algoma Steel. The distance between Site 1 and the batteries is about 200 or 300 metres. The site is also very close to the MOE air monitoring station where the interim air quality standard for B(a)P is frequently exceeded. Consequently, the presence of these compounds at detectable concentrations at Site 1 can reasonably be attributed to emissions from the coke oven batteries.

However, with most of the sites reporting non-detectable PAH concentrations, it is not possible to define the areal extent of the PAH deposition to foliage. On the basis of the data gathered in this investigation, PAH deposition can only be confirmed in the immediate vicinity of the coke ovens.

The use of foliage sampling to assess PAH emissions around other sources has produced mixed results. A trial of such methodology was performed in Hamilton near the Stelco and Dofasco steel mills, and in Windsor, across the Detroit River from the Great Lakes Steel mill in Detroit. In the case in Windsor, the sampling sites were one or more kilometres from the coke ovens and foliar PAHs were not detected. In Hamilton, at one sampling location about 1,700 metres from the Dofasco coke ovens, foliar PAH concentrations were very similar to those found at Site 1 near Algoma Steel. However, at other Hamilton sites at similar or greater distances from coke ovens, PAHs were not detected in the foliage samples.

Foliage sampling in the vicinity of a PAH source has occasionally been successful in delineating areal influence. This occurred in the vicinity of the UCAR Carbon plant in Welland. UCAR manufactures carbon and graphite electrodes, using coal tar pitch as a principal ingredient. Quantifiable foliar PAH concentrations occurred at several sites around this source on two occasions. However, on a third occasion it appeared that a heavy rain storm washed any accumulated PAH-containing particulates from the foliar surfaces and PAHs were not detected.

To see if this could be a factor in the observations made during the Algoma investigation, Environment Canada meteorological data for Sault Ste. Marie were examined. It was noted that on August 17, 1998, i.e. the day before the foliage sampling, 6.8 mm of precipitation was recorded at the airport. On August 14, 1998, i.e. four days before the foliage sampling, 2.6 mm was recorded. It is not possible to determine if these rainfalls were instrumental in washing the particulates from the foliage just prior to sampling. Should this investigation be repeated, careful

timing would be advisable to ensure an extended dry period before sampling so that the current areal extent of PAH deposition can be determined.

Table 2 represents the surface soil PAH concentrations. Assuming that atmospheric deposition is the mechanism responsible for the PAHs in soil, then these data represent the net accumulation of PAHs over the time that the soil was exposed to the deposition. It is important to note that PAHs can be degraded by microorganisms and therefore these concentrations do not necessarily represent the total PAH accumulation over the period of exposure.

Another point to remember is that, in urban areas, landscaping and construction activities can disturb indigenous soil. Therefore it is important to select sampling locations that have the greatest probability of minimal disturbance. Parks, cemeteries or similar green spaces, or old residential properties (i.e. without recent construction) are usually the most suitable sites. However, there can be no assurances that any two sampling locations contain soil that has been exposed to atmospheric deposition for similar periods of time.

Table 2 also contains three columns containing reference concentrations to which the investigation data can be compared. The first of these columns, titled OTR₉₈, contain statistically derived values representing the highest concentrations that might reasonably be expected in locations that were not subjected to contaminant deposition from nearby point sources. These values were developed through a sampling and analysis program that determined the range of inorganic and organic chemical concentrations in soil across the province of Ontario. Appendix A discusses the Ontario Typical Range (OTR₉₈) guidelines.

It should be noted that the sampling sites contributing to these guidelines were old urban parkland sites, and since some sites in the Algoma Steel investigation do not fit this category, application of these guidelines to such sites is technically inappropriate. However, for lack of OTR data for residential sites, the old urban parkland OTR₉₈ values remain the only reasonable alternative.

The other two columns, titled Table B ^{R/P} and Table B ^{I/C}, contain the human health or ecological based Table B criteria from the *Guideline for Use at Contaminated Sites in Ontario*. The intended use of the *Guideline* is to provide a means of assessing whether soil contamination at a property produces an unacceptable risk to receptor in the normal use or occupancy of the property. Different criteria may apply depending on whether the intended use is residential or parkland (R/P), or commercial or industrial (I/C). Appendix B provides more information about the *Guideline* and its application.

The only instance where one of the *Guideline* criteria is exceeded is at Site 20 where the concentration of benzo(a)pyrene is 2,200 ng/g. This is higher than both the Table B ^{R/P} and Table B ^{I/C} values. This case is highlighted with bold type in Table 2.

The shading in Table 2 highlights cases where the OTR₉₈ guideline is exceeded. There are seven sites where the OTR₉₈ guidelines were exceeded for several PAH compounds. These are Sites 1, 4, 12, 13, 14, 15 and 20. Sites 5, 7, 10, 16 and 19 do not contain any concentrations exceeding the OTR₉₈ guidelines.

At the remaining eight sites, Sites 2, 3, 6, 8, 9, 11, 17 and 18, only the data for dibenzo(a,h)anthracene is shaded. It should be noted that the OTR₉₈ guideline for this compound

is 77 <T ng/g. The flag "<T" indicates that the guideline value was less than the limit established by the analytical laboratory for unqualified data. This in turn indicates that many of the samples used to develop the guidelines contained dibenzo(a,h)anthracene at concentrations that were too low to be accurately quantified. Consequently, the OTR₉₈ guideline for dibenzo(a,h)anthracene should be considered an approximation and cases where the value is marginally exceeded should not be considered significant. This leaves only the first group of seven sites where PAH concentrations are unquestionably above the OTR₉₈ guideline.

In two of these seven, specifically Sites 1 and 20, these guidelines were exceeded by a significant degree. It is notable that Site 1 is the most proximal soil site to the Algoma Steel coke ovens, and given the observed deposition of PAHs to foliage near this site, it is reasonable to infer that the coke oven emissions are responsible for these soil PAHs.

However, Site 20, which actually has even higher concentrations, is considerably farther away, situated near the canal. Most of the sites that were actually closer to the coke ovens, such as Sites 2, 3, 7, 8 and 18, reported concentrations that were below the OTR₉₈ guidelines. Therefore, it is inappropriate to suggest that the coke ovens are responsible for the PAHs at Site 20. Given the fact that PAHs are not exclusively associated with coke ovens, the high concentrations at Site 20 may be due to other causes.

To reduce the data in Table 2 to more manageable proportions and to provide a visual representation of the relative PAH concentrations at the various sampling locations, the individual PAH concentrations for each sample were summed to produce "Total" PAH concentrations. Note that the remarks '<T' and '<W' were disregarded and the totals are simple sums of the data values. Note also that these totals are only of the 16 PAHs listed. The "Total" PAH concentrations are reported in Table 3.

Table 3: "Total" PAH Concentrations (ng/g dw) in Surface (0-5 cm) Soil

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
"Total" PAH	14,900	1,200	1,400	5,260	920	1,140	780	1,260	840	1,500
	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19	Site 20
"Total" PAH	2,080	3,500	4,460	4,000	3,280	680	1,480	2,920	840	33,020

These data are also represented in Figure 2 which was prepared by placing vertical bars, whose heights are directly proportional to the "Total" PAH concentrations listed in Table 3, at each respective soil sampling location symbol.

**Figure 2: Total (Relative) PAH Concentrations in Surface Soil Samples
Algoma Steel, Sault Ste. Marie - August 19, 1998**

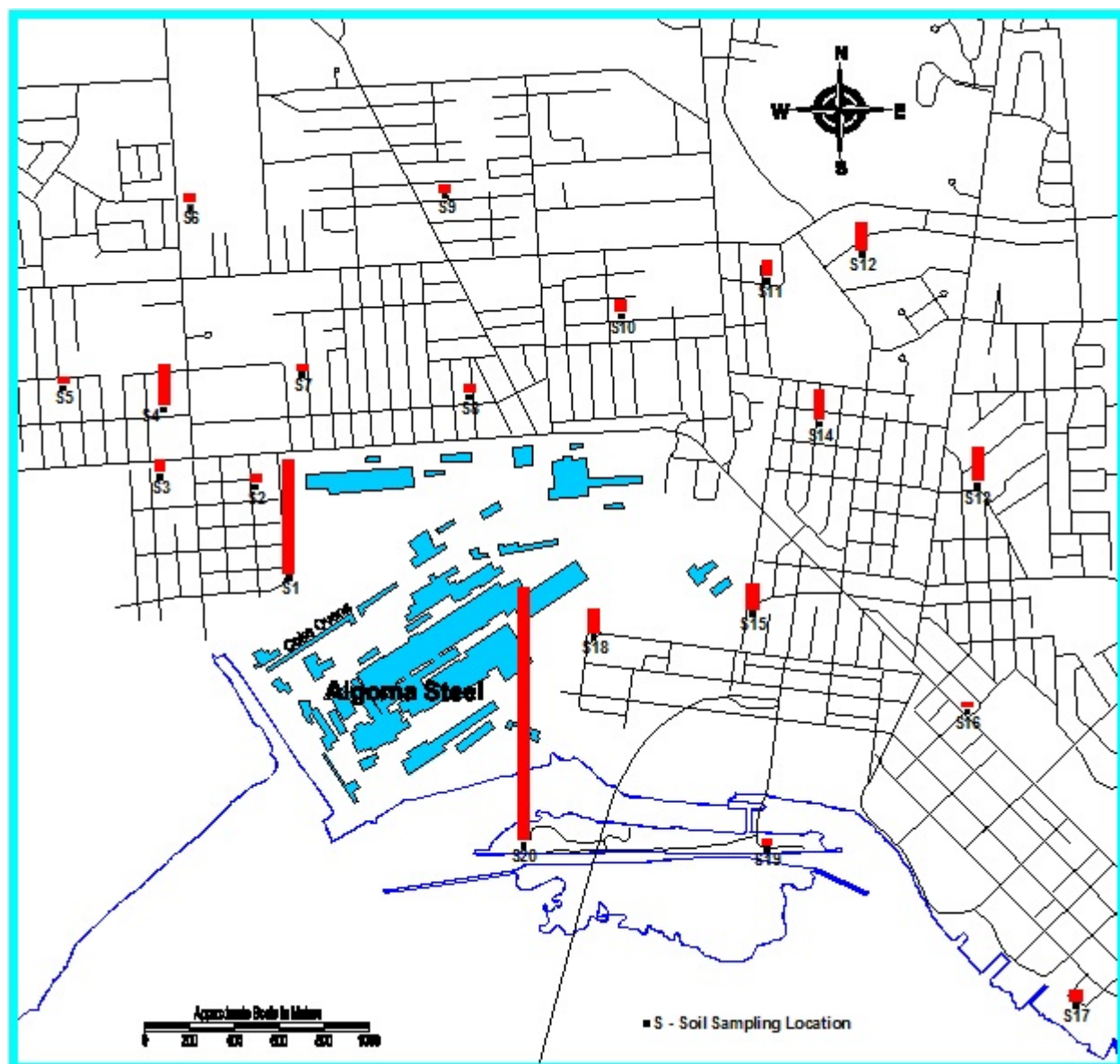


Figure 2 shows the pattern, or in this case the lack of one, in the soil PAH concentrations around Algoma Steel. What is particularly apparent is the relatively high concentrations at Site 1 which is very close to the coke ovens. Also seen are the elevated PAHs at Site 4 where the OTR₉₈ guidelines were likewise exceeded. However, between these two sites are Sites 2 and 3 with very low concentrations.

Figure 2 also shows how much higher the PAH concentrations are at Site 20, yet at Site 18 which is much closer to the coke ovens and the Algoma complex as a whole, the concentrations exceed the OTR₉₈ guidelines.

Beyond these we have Sites 13 and 14 also exceeding the OTR₉₈ guidelines, yet being located much farther from the coke ovens than several other sites that do not exceed.

What should not be ignored is the fact that so many sites do exceed. As was mentioned previously, soil at seven of the 20 sampling location contained several PAHs compounds that exceed the OTR₉₈ guidelines. A review of the characteristics of these sites failed to identify any probable cause for the elevated PAH concentrations at four of these (Sites 4, 12, 13 and 14) as they were residential or school properties. Site 15 was near a railway line where there is always a potential for PAH contamination from railway tie treatment. It is quite conceivable that, historically, coke oven emissions were more significant and more widely dispersed. In the interim, many sites were disturbed so that historic impacts are now masked.

It is also worth reiterating that the only case where a *Guideline* criterion was exceeded was at Site 20. This site, located near the ship canal through St. Mary's Island, is in an isolated and undeveloped area. The reason for the highest soil PAHs at this particular locations remains inexplicable.

Conclusions:

This investigation identified marginal yet measurable PAH concentrations of Norway Maple foliage at the sampling site which was the most proximal to the Algoma Steel coke ovens. This in itself is an indication that PAH emissions do occur and are impacting the nearby residential community. The observed elevated soil PAH concentrations at this locations, together with air quality data showing that the interim standard for benzo(a)pyrene is also exceeded here, confirm coke oven emissions impacting at least part of the residential neighbourhood near Algoma Steel.

The pattern of soil contamination was not sufficiently clear to permit attribution to Algoma Steel. While several sites contained PAHs that exceeded the OTR₉₈ guidelines, these were not necessarily sites where coke oven emissions would be expected to have the most significant impact.

Appendix A

Derivation and Significance of the MOEE "Ontario Typical Range" Soil Guidelines.

The MOEE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the OTR_{98} is the actual guideline number*) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOEE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98} .

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOEE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average*, and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOEE Report No.: HCB-151-3512-93, PIBs No.: 2792, ISBN 0-778-1979-1.*

Appendix B

Derivation and Significance of the MOE Soil Clean-up Guidelines

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg, agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria* **may not** ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded **and** where the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*. In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defensible, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*.

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3.